Kansas State University

Manhattan, Kansas 66504

Engineering Experiment Station
Seaton Hall

April 20, 1966

Miss Winnie M. Morgan, Technical Reports Officer
Office of Grants and Research Contracts
National Aeronautics and Space Administration
Washington, D. C. 20546

RE: SC-NsG-692/17-001-005

Dear Miss Morgan:

We are pleased to enclose the status reports for NASA Grant NsG-692/17-001-005 covering the period September 1, 1965 through February 28, 1966. This report is made up of eight separate reports as follows:

1.	The Measurement of Lunar and Planetary Radiation	Dr. E. Brock Dale	Physics
2.	The Effect of Gravitational Fields on Enzymatic Reactions Occurring in Inhomogeneous Systems	Dr. R. K. Burkhard	Biochemistry
3.	Analytic Studies in the Learning and Memory of Skilled Performance	Dr. Merrill E. Noble	Psychology
4.	Optimization of Space System Design	Dr. G. F. Schrader	Industrial Engineering
5.	Experiments with Ultraviolet Light	Dr. C. E. Mandeville	Physics
6.	Width of Tracks of Heavy Ions in Emulsions and Other Media	Dr. Robert Katz	Physics
7.	A linear Operator Analysis of Single Side-Band Modulation System	Dr. C. A. Halijak	Electrical Engineering
8.	Determination of Optimum Nozzle Contours for the Expansion of Dissociated Gases by Methods of the Variational Calculus	Dr. James Bowyer	Mechanical Engineering

Ten copies of this report are enclosed and ten additional copies will be included with the proposal for renewal of this grant which will be transmitted to NASA within the next two or three weeks.

If there are any questions regarding this report or any additional information is needed please do not hesitate to call.

Cordially,

Leland S. Hobson, Secretary
KSU Research Coordinating Council

cc: Mr. John R. Craig, Research Program Manager, NASA
Dr. John Lott Brown, Chairman, Research Coordinating Council, KSU
Dr. A. B. Cardwell, Director, Bureau of General Research
Dr. Floyd Smith, Director, Agriculture Experiment Station, KSU

THE MEASUREMENT OF LUNAR RADIATION

E. Brock Dale, Department of Physics

NASA Grant NsG-692

The objectives of this research are to measure cooling rates of selected areas on the moon and to monitor total radiation through the 8-14u window from Mars, Venus, and possibly Mercury.

At the date of our last report (September 1965) the photometer was in the final stages of construction. A description of the gross features of the photometer was included in the report. Since the date of that report, we have been refining, adjusting, and testing the photometer apparatus.

Photometer Details

The detector is mounted in an aluminum dewar, and cooled by a Cryotip open cycle refrigerator. This arrangement appears to be quite successful. We have given some thought to attaching pumps and surge tanks to allow closed-cycle operation, and are awaiting the advice of the manufacturer. The most troublesome feature of the system now in use is the necessity of evacuating the dewar before use. We intend to install a small appendage-type ion pump with titanium booster.

A tracking device has been added. This consists essentially of a coated germanium disc set in front of the detector at such an angle that it transfers the image plane to the focal plane of a bifilar micrometer eyepiece. During a lunar scan, the telescope is held fixed relative to the earth. The cross hairs are adjusted so that points on the lunar image are parallel to the cross-hairs of the eyepiece. For each scan of a given series, the movable cross hair is held on a reference point of known selenocentric coordinates. The fixed cross-hair coincides with the path being scanned. The selenocentric coordinates of points along the path scanned are computed from knowledge of the distance between the cross-hairs, the time Δt from initial (or final, depending on the direction of scan) contact of the detector with the moon's image, the geocentric latitude and longitude of the telescope, and ephemeris and refraction data.

The recording system consists of a low-noise pre-amplifier, and intermediate tuned amplifier with a half power bandwidth of 20 CPS, a phase-sensitive (lock-in) amplifier, and a recorder. The entire system is tuned to the chopper frequency of 594 cycles per second. The intermediate amplifier was constructed when it was discovered that electrical noise pulses (from switches, motors, etc.) caused the lock-in amplifier to switch phases, resulting in reversal of the polarity of the output signal. A block diagram of the apparatus is shown in Figure 1.

As the photometer now stands, both the reference beam and the beam from the object under surveillance undergo three reflections and pass through a coated Ge window and an 8.5 - 14.0 micron filter. The estimated transmission loss of the entire system, including telescope, is 50 per cent. The field stop in front of the detector has a diameter of 0.35 mm. This is somewhat smaller that optimum since the diameter of the first dark ring of the telescope diffraction pattern is 0.48 mm.

Performance

In figure 2, we have plotted the 8.5 - 14. micron flux through the .35 mm. aperture for extended objects at temperatures from 100°K to 400°K, assuming no transmission losses. Figure 3 is the record of a trial scan across the moon, made with an integration time of one second. The peak-to-peak noise is about one third of the smallest chart division, and the maximum deflection, corresponding to a temperature of 390°K is 15 divisions. The calculated flux through our system for a body at this temperature, neglecting transmission losses is 3×10^{-8} watt. This the noise-equivalent power of the entire system is 6×10^{-10} watt. This is equivalent to a peak-to-peak temperature variation of 2° at 400°K, 4° at 300°K, and 15° at 200°K. It is equivalent to the total signal at 185°K when used with our present optics. This represents a signal-to noise ratio sufficient for measuring the illuminated parts of the moon, but it is not adequate for measurements beyond the terminator without sacrifice of resolution.

The signal-to noise ratio could be improved by increasing the diameter of the detector aperture or reducing the size of the image, or both. Thus, although the instrument as it stands is not suitable for planetary scanning, it is quite adequate for measurement of total radiation from Mercury, Venus, and Mars, because, for this purpose, the effective aperture of the detector needs to be about nine times its present value in order to accomodate the entire disc of Venus and Jupiter. In the coming months of this year, we will continue to work toward improved detector sensitivity, but will proceed with the relatively simple task of revising the optics to increase the detector aperture.

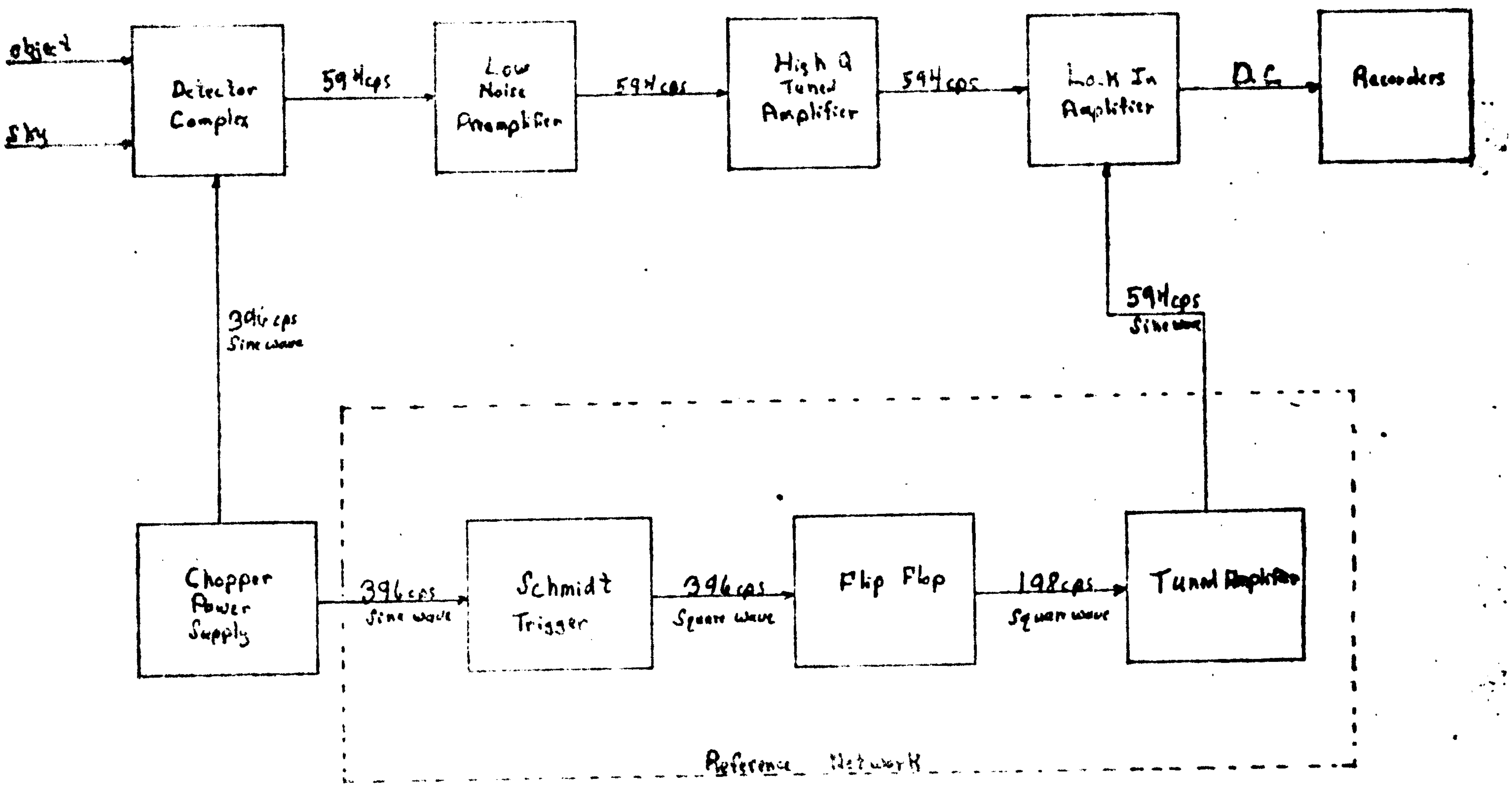

FIGURE 1. BLOCK DIAGRAM OF CHOPPER-AMPLIFIER SYSTEM

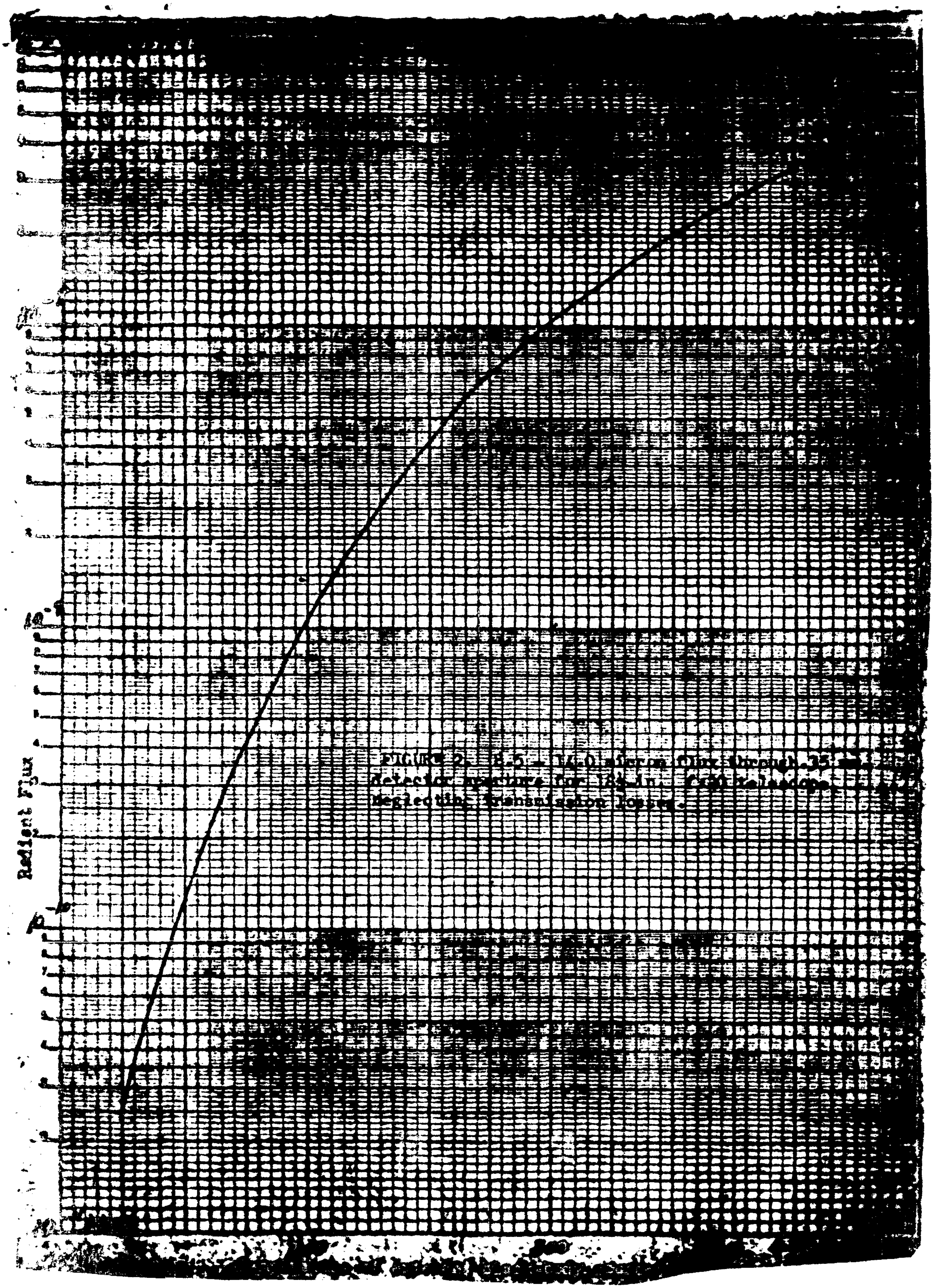

FIGURE 2. 8.5 - 14.0 micron flux through .33 [illegible] detector aperture for 18 in. [illegible] telescope. Neglecting transmission losses.

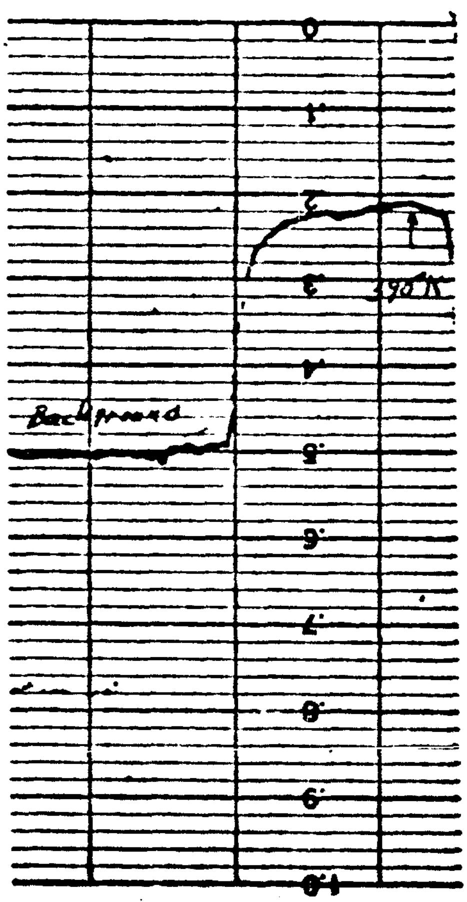

Figure 3. Test scan across illuminated lunar surface.

Semi-annual Report

for

NASA Project NsG-692

"The Effect of Gravitational Fields on Enzymatic Reactions Occurring in Inhomogeneous Systems"

prepared by

R. K. Burkhard, Principal Investigator

March 24, 1966

Studies involving centrifugation of enzymatic systems have been continued. Data obtained during the past six months indicate that earlier conclusions were incorrect. The effects noted earlier were thought to be due to some factor other than a rise in the temperature of the centrifuge rotor. This conclusion was based on a knowledge of initial and final temperatures of the rotor and the temperature dependance of the enzyme employed. Much of the earlier work has been repeated using a centrifuge with which it is possible to maintain better control of the rotor temperature. It has been found that if the rotor temperature is kept constant the previously observed effect disappears.

A study has been made to determine how easily a soluble substrate can enter the mitochondrial pellet which forms during centrifugation. It has been found that when the pellet is formed at 3000 x g the substrate can still enter the pellet rather easily. This is not true, however, when the pellet is formed at 100,000 x g.

A study has been made to determine whether the increased hydrostatic pressure which accompanies centrifugation will affect mitochondrial activity. No such effects were observed even up to pressures close to a hundred atmospheres.

Analytic Studies in the Learning and Memory of Skilled Performance

Merrill E. Noble

Department of Psychology

NASA Grant NsG 692

During the six month period ending February 28, 1966, one additional experiment was completed. Results of earlier research done under this grant on visual acuity in the peripheral retina suggested that a wider range of interstimulus intervals than has previously been investigated was needed. Consequently, 20 interstimulus intervals from 0 to 700 milliseconds, were employed in an investigation of the relationship between interstimulus interval and the ability to perceive the coincidence or non-coincidence between lines presented to the peripheral retina (4.75° nasal) of the right eye. Trained subjects reported which of two vertical lines was nearer, using the method of constant stimuli. The data of this experiment are now being analyzed.

The next experiment, which is now underway, will investigate the effects on vernier acuity of two visual forms, closed and open triangles (i.e., triangles and V's). Work conducted last year indicated there was greater vernier acuity with the closed triangle, and we now are following up this lead, which has interesting theoretical as well as practical implications.

Kansas State University

Manhattan, Kansas 66504

Department of Industrial Engineering
Engineering Shops Building

March 24, 1966

To: Research Coordinating Council
Kansas State University

Subj: Semi-Annual Progress Report - NASA Grant No. NSG-692

Title: Optimization of Space System Design

Principal Investigator: Dr. G. F. Schrader

The work accomplished and progress made on this project during the period 9-1-65 to 2-28-66 is summarized as follows:

Consistent with the previous work done under this grant in the development and application of optimization methods to aerospace systems design, emphasis during the past six months on this project has been placed on the development or modification of cost/effectiveness models applicable to space programs.

In consideration of the high development and operation costs incident to the fulfillment of space program objectives, evaluations of proposed systems must be undertaken before a decision can be made to produce a given system. Comparisons must be made of alternative systems in terms of guidelines and objectives of the overall space program and particular mission requirements. In order that valid comparisons might be made, an analytical approach must be developed which involves performance measures common to the system under study and constraints particular to a given program. It is also desirable to have within the methodology a procedure to find the most effective program or programs which, when used in proper sequence will result in an optimal allocation of funds.

Part of the activity on this project to date has involved an evaluation of existing cost/effectiveness models and procedures to determine their applicability and manipulatability in so far as optimization methods are concerned. For example, the Air Force Systems Command has a method, developed by WSEIAC (Weapons System Effectiveness Industry Advisory Committee), which is used to evaluate the cost and the effectiveness of a proposed system. The main objective of this method is to obtain as efficient a defense posture as is possible within the constraints of cost and effectiveness. NASA has developed a program possessing some similarity to the WSEIAC system, but with differences in so far as measures of performance are concerned. The objective of this study is to develop a more effective basis for cost/effectiveness optimization in terms of the performance characteristics required in a non-defense oriented space program such as NASA.

Work on this project has reached a stage of development wherein cost and effectiveness functions, and equations representing NASA programs are being formulated in such a way as to permit the application of cost-effectiveness approaches in the analysis of an integrated space program. These relationships are being formulated in such a way as to permit the application of the discrete maximum principle approach to optimization.

Concurrent with the above study, certain specific problems presented in the WSEIAC system are being reformulated for purposes of optimization through the use of the discrete maximum principle. One problem in particular involves weight allocation between guidance, warhead and penetration aid components so as to maximize effectiveness of the final missile stage.

During this period, work was completed on a phase of activity concerning the application of Pontryagin's maximum principle to the optimization of simple discrete multistage stochastic processes. The results of this work have been summarized in a Kansas Engineering Experiment Station Special Report No. 64 entitled "The Stochastic Discrete Maximum Principle for Simple Processes." Further work is anticipated on this to expand the concepts to more complex systems involving probabalistic elements. An attempt will then be made to adapt this approach to the optimization of systems cost-effectiveness models.

George Schrader

Semi-Annual Report of the Work

of

NASA Grant NsG - 692

Experiments With Ultraviolet Light

Principal Investigator: C. E. Mandeville

Kansas State University

Manhattan, Kansas

24 March 1966

During the period 1 September to 28 February 1966, the equipment relating to the project has been improved by addition of

1. A Fluke High Voltage Supply.
2. Servo-Tek constant speed motor system, variable in rotation frequency from 30 rpm to 3600 rpm.
3. Introduction of ultraviolet sensitive photomultiplier tubes as detectors.
4. Emitter-Follower circuits for impedance matching purposes in treating pulses from photomultiplier tubes.

At present on order is an additional constant speed motor and a specially constructed photo-detector which responds only to the ultraviolet.

The above cited equipment is being utilized in a study of ultraviolet and visible light generated by the relative motion of contiguous surfaces. of mercury and glass. A ball of corning 9741 glass, containing Hg and He is spun by the constant speed motor; the light output is measured by the photomultiplier tubes. The pulses of light emission are observed upon an oscilloscope, and at about 480 rpm, are found to decrease abruptly in height. Thus decrease in pulse height and light emission may be in some manner related to the transit time of electrons from Hg to glass. As the time of rotation of the ball approaches the transit time, the light emission decreases.

NASA Grant NsG-692   Progress Report   15 March 1966

Width of the tracks of heavy ions in emulsions and other media, Robert Katz, Principal Investigator

Emulsion stacks exposed last summer have been scanned and are now being measured. A new measuring technique is being employed. In previous work images of the tracks were projected onto a screen and were traced manually to obtain the track area. At present, photographs of the track are being made onto 70 mm film, and these are being enlarged onto paper rolls. The enlargements are then traced manually by several observers. Their determinations will be compared.

Arrangements are being made to expose additional emulsion at the Berkeley HILAC to a beam of known heavy ions, and to the cosmic rays in a balloon, through courtesy of Prof. Peter Meyer, University of Chicago.

The following papers have been presented:

Randomness, Robert Katz, Bull. Am. Phys. Soc. 11,113(1966).

Simulated Radioactivity, Robert Katz, Am. Assn. Phys. Teachers, New York Meeting, January 1966.

A paper entitled Transverse Distribution of Ionization Energy, R. Katz and J.J. Butts, was submitted to the Physical Review.

A paper entitled Theory of RBE for Heavy Ion Bombardment of Dry Enzymes and Bacteriophage, Robert Katz and J.J. Butts, has been submitted to the III International Congress For Radiation Research, Cortina D'Ampezzo, Italy, for presentation 26 June- 2 July 1966.

Copies of the abstracts and the paper are attached.

Simulated Radioactivity *. Robert Katz, <u>Kansas State University</u>. An "experiment" to simulate radioactive decay is easily performed with a table of random numbers or a random number generator. In this simulation a set of "nuclei" are imagined to be indexed consecutively. Random numbers are drawn sequentially. The Appearance of the index number of a particular nucleus is interpreted as a signal that it has disintegrated. A plot of the number of residual nuclei versus the number of draws yields the radioactive decay curve, with fluctuations. The procedure is a precise realization of the conventional probabilistic derivation of the radioactive decay law, if indeed the random number generator is truly unbiased.

* Supported by NASA and NSF grants.

For the New York Meeting, AAPT, January 1966

26 JANUARY 1966

SERIES II, VOL. 11, NO. 1

BULLETIN

OF

THE AMERICAN PHYSICAL SOCIETY

1966 Annual Meeting at New York • 26–29 January 1966

GG2. **Randomness.*** ROBERT KATZ, *Kansas State University.* —The word *random* has an evasive meaning. Though it is properly applied only to a process, there is no way to evaluate the randomness of a process except through its product. Simulation techniques depend on the likelihood that the output of a particular real generator could have occurred (with good probability) from an ideal perfectly random generator. A new likelihood test has been developed, based on the binomial distribution, that appears to be a useful supplement to tests currently in use. A perfectly random generator has a probability identically equal to 10^{-a} of drawing any one a-digit number. We find the actual tally of t times repeated numbers after n draws, and compute its deviation from the expected tally (derived from the binomial distribution) in units of the standard deviation. These quantities, $\chi(n,t)$, and the sum of their squares, $\chi^2(n)$, may be plotted against n to reveal systematic defects in the generator. Alternatively, arbitrary bounds on χ or χ^2 may be programmed into a computer to trim away such defects in the output of a pseudorandom generator.

* Work supported by the National Aeronautics and Space Administration and the National Science Foundation.

THIRD INTERNATIONAL CONGRESS FOR RADIATION RESEARCH

CORTINA D'AMPEZZO (Belluno), ITALY

26 June - 2 July, 1966

THEORY OF RBE FOR HEAVY ION BOMBARDMENT OF DRY ENZYMES AND BACTERIOPHAGE.

ROBERT KATZ AND J. J. BUTTS
Kansas State University, Manhattan, Kansas, U.S.A.

The response of dry enzymes and bacteriophage to heavy ion bombardment may be predicted from their response to γ-ray irradiation, without any assumption of molecular size or structure. The computed inactivation cross-sections are in good agreement with measured values for the enzymes β-Galactosidase and Trypsin, and for T-1 and ØX-174 phage, as reported in the literature, in bombardments with ions for which Z ranges from 1 to 18, at β from 0.065 to 0.145. For these substances the value of D-37 for γ-rays ranges over two orders of magnitude. In these bombardments the inactivation cross-section ranges over five orders, and the LET over two orders of magnitude. The average deviation of theory from experiment is less than fifteen percent. Since Z and β are sufficient to determine the LET, and with D-37 are here shown to determine the inactivation cross section, the present work yields a theory of RBE. In the limit of large β and large D-37 we find that the RBE approaches one. In the computation the response of these substances to both γ-rays and heavy ions is taken to be through secondary electrons. The ionization dosage delivered by a passing ion is cylindrically symmetrical, and is strongly dependent on the radial distance from the ion's path. We compute the dosage function at speed βc (and effective charge Z^*) of the passing ion from a) the delta ray distribution formula, b) an extrapolated range-energy relationship of the form $x = kw$ (with $k = 10 \mu gm/cm^2 keV$), and c) an assumption of normal ejection. Scattering is assumed to be accomodated by the range-energy relation. Water is taken to be a good approximation to biological matter. Applying the one-hit γ-ray inactivation formula to the computed dosage distribution we find the probability for inactivation as a function of r. Integration of the probability over all r yields the cross-section. In this calculation all knowledge of the size and structure of the molecule is thought to reside in the γ-ray D-37 dose.

Work supported by the National Science Foundation and the National Aeronautics and Space Administration.

Submitted to the Physical Review

Transverse Distribution of Ionization Energy†

Robert Katz and J.J. Butts

Kansas State University, Manhattan, Kansas

A simplified theory of the spatial distribution of ionization energy, appropriate to transverse distances of about 50-5000 Å, has been verified by use of radiobiological data. The response of bacteriophage and enzymes to heavy ion irradiation is shown to be predictable from their response to γ irradiation. In this region the range of electrons appears to be directly proportional to their energy.

I. Introduction.

An earlier study[1] of the tracks of heavy ions in electron sensitive emulsion has been applied to the conditions appropriate to a biological medium, in order to take advantage of the considerable body of data on the interaction of γ rays and charged particles with these materials. Knowledge of the sensitive response of photographic emulsion is rather unclear, owing in part to uncertainties in grain size, composition, and prior treatment. On the other hand bacteriophage and enzymes are extremely uniform, and their response to γ irradiation follows an exponential law in which the survival may be

† Supported by NASA and NSF Grants

characterised by the D_{37} dosage, the dosage at which 37 percent (1/e) of the population retains its biological function. Irradiation of these materials with beams of charged particles again leads to an exponential survival curve from which a characteristic parameter, σ, the cross section for inactivation may be obtained.

Because of the greater uniformity, the smaller grain size (down to molecular dimensions), and the availability of empirical knowledge of the sensitivity of bacteriophage and enzymes, these substances are ideally suited to test the theory of transverse distribution of ionization energy. Indeed the relative insensitivity of these biological materials, that is, their small inactivation cross sections, leads to a direct and simple calculation.

From the viewpoint of the radiobiologist, the present reinterpretation of his data constitutes a new theory of the inactivation cross section. Indeed we will show that σ can be derived from D_{37} without any further assumption about the structure of the phage or the enzyme.

II. Theory.

The simplest biological materials are thought to consist of "targets", or sensitive units, imbedded in a passive matrix. We consider here only "one-hit" processes in dry materials, in which a single ionization within the sensitive unit (say, a single molecule which loses its function if one of its many bonds is broken) will inactivate it. The probability for inactivation may be described by the Poisson formula[2], which for a one-hit process reduces to

$$P = 1 - \exp(-D/D_{37}) . \qquad (1)$$

where D is the dosage of randomly distributed ionization energy, and D_{37} is the dosage for 37 percent survival. Since the interaction of both γ rays and energetic ions is through secondary electrons, we infer that Eq.(1) is equally applicable to both processes, and that observed differences in response to these different irradiations are because of the different spatial distribution of the ionization energy.

If the dosage of ionization energy is D within a shell of thickness dx at radius x from the ion's path, the inactivation cross section, σ, may be found as the integrated inactivation probability, or

$$\sigma = \int_0^\infty 2\pi x \, dx \, (1 - \exp(-D/D_{37})) . \qquad (2)$$

To find D we note that we need a range-energy relation for electrons of energy less than a few keV. In the absence of available data, we have extrapolated the results of Kanter and Sternglass[3] for aluminum in this energy region to obtain

$$x = k\,w\,, \qquad (3)$$

where $k = 6{,}230$ gm/cm^{2}erg (= 10 μgm/cm^{2}keV).

We make use of the conventional delta ray distribution formula

$$dn = C\,\frac{Z_e^2}{\beta^2}\,\frac{dw}{w^2}\,, \qquad (4)$$

where

$$C = \frac{2\,\pi\,N\,e^4}{mc^2}\,, \qquad (5)$$

which gives the number of delta rays per unit path length, dn, having energy between w and w + dw, produced by an ion of effective charge Z_e moving with speed βc, where m is the electronic mass and e is the electronic charge, and N is the number density of electrons in the material. We approximate biological matter by water, for which $N = 3.35 \times 10^{23}$ electrons/gm, and density 1, and assume that the range energy curve for electrons in aluminum is equally valid for water.

Charge pickup is taken into account through an expression from Barkas[4] giving the effective charge of an ion in relation to its atomic number Z' and its speed βc, as

$$Z_e = Z'e\left(1 - \exp(-125\beta/Z'^{2/3}) \right)\,. \qquad (6)$$

The data to which the present calculations are compared were obtained with ions for which β ranges from 0.065 to 0.145. In these cases the delta rays of energy below 1 keV, which are of primary importance here, may be considered to be ejected normal to the ion's path, from elementary kinematic considerations. Taking w_x to be the energy of the delta ray of range x, and $w_{max} = 2mc^2\beta^2\gamma^2$ to be the range of the most energetic delta ray permitted by kinematics on collision between a free electron and an ion moving with speed βc, we find the number, M, of electrons passing through the cylinder of thickness dx and radius x coaxial with the ion's path to be

$$M = \int_{w_x}^{w_{max}} dn = C\frac{Z^2}{\beta^2}\left(\frac{1}{w_x} - \frac{1}{w_{max}}\right) . \qquad (7)$$

The ionization energy per unit volume delivered to this shell of radius x, the dose $D(x,\beta,Z)$, is then obtained from Eq.(3) and Eq.(7) as

$$D(x,\beta,Z) = \frac{M\frac{dw}{dx}dx}{2\pi x\, dx} = C\frac{Z^2}{\beta^2}\frac{1}{2\pi x}\left(\frac{1}{x} - \frac{1}{R}\right) , \qquad (8)$$

where $R = k\, w_{max}$ is the range of the delta ray of maximum energy. Limits on the validity of Eq.(8) may be expected to arise from electron binding, and from failure of the extrapolated form of the range energy relationship. We estimate the expression to be valid between 50 and 5000 Å .

After substituting the expression for dosage distribution from Eq. (8) into Eq.(2), a value of D_{37} is assigned by trial and Eq.(2) is integrated numerically until values of the cross section reasonably close to experiment are obtained. Note that in Eq.([illegible]) x is generally much less than R, in the cases of interest here. For values of x much smaller than R the dose is independent of the constant k of the range energy relation, Eq.(3), so that precise knowledge of this relation for slow electrons is not required in the dose computation or in the computation of the cross section.

III. Results.

Experimental results and their comparisons with theory are given in Table I. The data were reported by Dolphin and Hutchinson[5], and Shambra and Hutchinson[6] from work with the Yale Heavy Ion Accelerator, and by Fluke, Brustad and Birge[7], with the Berkeley HILAC. The table gives the value of β, Z' and σ for each irradiation, as well as experimental values of the D_{37} dose for each of the bacteriophages T-1 and φX-174 and the enzymes β-Galactosidase and Trypsin on which work was reported.

One may estimate that the error in the experimental cross sections is of the order of [illegible] percent. Experimental values of D_{37} may have greater uncertainty. For example, the reported D_{37} dose for Co^{60} (and 25 MeV maximum energy [illegible]) irradiation of T-1 phage is 5.5×10^7 ergs/gm [6] and 4×10^7 ergs/gm [8] (and 2.3×10^7 ergs/gm [9]), according to the referenced observers. The average of these values is 3.9×10^7 ergs/gm, which compares favorably with our adjusted value of 3.5×10^7 ergs/gm .

IV. Discussion.

The overall agreement between theory and experiment is quite good, in view of the simplifying assumptions used in the calculations. In all calculations the electron density of water was used as an approximation to the electron density of the biological material. A range-energy relation extrapolated from data on the penetration of electrons in aluminum was applied to water. The initial direction of the delta rays was taken as normal to the ion's path, an assumption whose kinematical validity rests upon weak collisions between ions and free electrons. Both in this assumption regarding the angular distribution of the low energy electrons and in the application of the delta ray distribution formula, free electrons are assumed. Surely for delta rays of the lowest energy which were initially associated with the Oxygen K-shell, the bounds of credibility are strained. Nevertheless the neglects in the theory do not appear to exceed the uncertainty in the experimental data, and indeed the interpretation of the radiobiological data has been greatly clarified.

The basic procedures used here are the same as those used in the computation of the width of tracks in emulsion, and serves to corroborate them. We anticipate that Eq.(3), which gives the range of electrons of very low energy, and Eq.(8) which describes the transverse distribution of ionisation energy about the path of a charged particle may be of interest in other radiation damage studies.

SUBSTANCE	IRRADIATION	DOSAGE OR CROSS - SECTION	
	Z γ E	EXPERIMENT	THEORY
[illegible][3]	D-37	3.1 (9) erg/cm^3	5.0 (8) erg/cm^3
	6 0.145	2.8 (-12) cm^2	2.7 (-12) cm^2
	8 "	4.5 "	4.5 "
	9 [illegible]	[illegible].7 [illegible]	[illegible]
[illegible][5]	D-37	[illegible] ([illegible]) erg/cm^3	[illegible] erg/cm^3
	[illegible]	[illegible] cm^2	[illegible] cm^2
	6 0.145	[illegible]3 (-[illegible]) "	[illegible].7 ([illegible]) "
	8 "	6.1 "	[illegible]
ØX-174 Phage[6]	D-37	5.0 (7) erg/cm^3	8.0 (7) erg/cm^3
	2 0.145	3.5 (-12) cm^2	2.0 (-12) cm^2
	6 "	1.6 (-11)	[illegible] (-11)
	8 "	2.3 "	2.[illegible] "
	18 "	10.5 "	[illegible] "
T-1 Phage[3]	D-37	3.9 (7) erg/cm^3	3.5 (7) erg/cm^3
	2 0.145	[illegible].4 (-12) cm^2	[illegible].2 (-12) cm^2
	6 "	3.8 (-11)	3.0 (-11)
	8 "	5.3 "	5.0 "
	9 "	5.3 "	[illegible].1 "
	10 "	5.4 "	7.2 "
	18 "	13.7 "	13.2 "
T-1 Phage[7]	2 0.085	1.0 (-11) cm^2	0.87 (-11) cm^2
	[illegible] 0.196	0.38 "	0.35 "
	[illegible] 0.075	5.4 "	6.0 "
	6 0.140	3.6 "	3.15 "
	6 0.069	7.9 "	9.18 "
	8 0.182	5.9 "	5.5 "

Table I. Inactivation of Enzymes and Bacteriophage by γ-rays and Particle Bombardment. Superscripts in the left hand column refer to the sources of the data.

References

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[5]G. W. Dolphin and F. Hutchinson, Radiation Research 13, 403 (1960)

[6]P. E. Shambra and F. Hutchinson, Radiation Research 23, 514 (1964)

[7]D. J. Fluke, T. Brustad, and A. C. Birge, Radiation Research, 13, 788 (1960)

[8]D. J. Fluke and F. Forro, Jr., Radiation Research 13, 305 (196

[9]E. Biochem. Biophys.

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A LINEAR OPERATOR ANALYSIS OF A SINGLE SIDEBAND MODULATION SYSTEM

Charles A. Halijak
Department of Electrical Engineering
NASA NsG-692

This investigation utilizes two linear (as distinguished from the general bilinear) multiplication operations as basic tools. If f(t) is a given function of exponential order, then the required linear operators are:

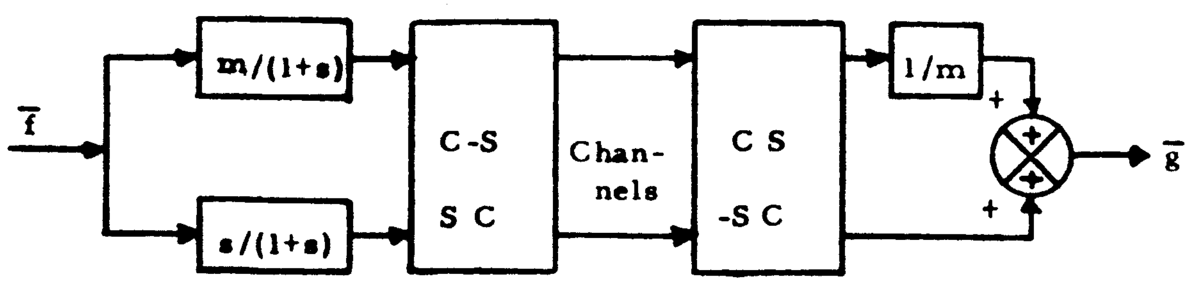
$$\overline{f(t)\cos\omega t} = \mathrm{Re}\,\bar{f}(s+j\omega) \equiv C\bar{f};$$

$$\overline{f(t)\sin\omega t} = \mathrm{Im}\,\bar{f}(s-j\omega) \equiv S\bar{f}.$$

Here, $\bar{f}(s)$ is the Laplace transform of f(t). These C and S transforms adequately describe double-sideband-suppressed-carrier modulation and naturally lead to a description of single-sideband (SSB) modulation.

An existence theorem for an ideal SSB modem (short for modulator-demodulator) has been discovered.

THEOREM: If the input signal is $f(t) = \cos mt$ and $\begin{pmatrix} C & -S \\ S & C \end{pmatrix}$ is a transfer operator matrix, then the following block diagram



has an output $\bar{g}$ identical to the special input signal $\bar{f}=s/(s^2+m^2)$ and both channel signals are pure upper sideband signals. Moreover, if m is fixed in the diagram but f(t)=cos n t and n is different from m, then each channel signal is contaminated with a lower sideband signal.

Lengthy algebraic calculations have yielded an unexpected result; namely, there exist common factors in the amplitudes of the upper sideband signal and contaminating lower sideband signal so that a simplified amplitude ratio is possible. Studies are continuing for determining normalizations for best description of this amplitude ratio.

A literature survey has been initiated and these results seem to be novel and fundamental.

DETERMINATION OF OPTIMUM NOZZLE CONTOURS FOR THE EXPANSION OF DISSOCIATED GAS BY METHODS OF THE VARIATIONAL CALCULUS

Dr. James Bowyer, Jr. Mechanical Engineering Department

NASA NsG-692

Third Semi-annual Report
(First Semi-annual Report of Second Year)

Since the end of the first year's activities and the completion of the Ph.D. thesis of R. R. Berns entitled, "Optimum Nozzle Contours for a Dissociating Gas with a Catalyst", relatively little has been done toward extending these results. A more comprehensive report of last year's activities is still being prepared. An abstract of these results will be submitted to the papers committee of the XVIIth International Astronautical Congress for presentation in October, 1966.

Because the research activities of this principal investigator are closely supported by the Ph.D. candidates under his direction at a particular time, a research effort by Mr. Bong L. Koh entitled, "Supersonic Base Drag in the Presence of Base Burning" has been supported by NsG-692 funds during the past six month period. This support is justified on the basis that the subject of Mr. Koh's thesis is of considerable current interest in aerospace operations. Mr. Koh's thesis is an extension of the Ph.D. thesis of L. R. Davis entitled, "The Effect of Chemical Reactions in the Turbulent Mixing on the Dynamics and Thermodynamics of Wake Flow Fields". Davis' thesis was written at the University of Illinois under the direction of Dr. H. Korst. A related study was completed by the principal investigator of this project; this fact explains current activities in this area. The thesis associated with Mr. Koh's and the principal investigator's research will be defended during this spring semester and will be submitted as a report of activities completed under NASA Research Grant NsG-692.

Mr. Norbert Demeke, another Ph.D. candidate and advisee of this principal investigator, has recently complèted his preliminary examinations and is commencing study of the primary subject of this research grant. Mr. Deneke is well prepared for the study of the dynamic problems involved in the optimization of the nozzle contour in the case of a chemically reacting gas flow through the nozzle. It is anticipated that the principal investigator and Mr. Deneke will resume research of the "Determination of Optimum Nozzle Contours for the Expansion of Dissociated Gas by Methods of the Variational Calculus" immediately and that this research will proceed in the direction indicated in the proposal for this second year's activities under this Grant.